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It's T time: A study on the return period of multivariate problems

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One of the most important tasks a hydrologist must face is the proper estimation of the 'design values' of a natural variable corresponding to a given Return Period, T, of failures of the hydraulic 'structure' to be designed or verified. Sometimes the 'structure' is simply the embankments, the failure of which corresponds to the outflows of flood runoff on the surrounding land. The widely adopted definition of T, in a problem regarding the maxima of hydrological variables, is "the average time elapsing between two successive occurrences of an event exceeding a certain magnitude of the natural variables". If T is referred to the minima, the symmetric definition pertains to the "average time between two periods during which the variable ranges below a given magnitude".

Conventional (and the only accepted) approaches for estimation of T involve a single natural variable (i.e. flood-peak of a river at a given cross section, the daily maximum discharge, the maximum daily rainfall depth observed at a given rain-gauge). The method of estimation of T entails a frequency analysis of the variable of interest, where the design value of a given T is needed to design the structure of interest (e.g. dams, sewers). In other words, T is used as the index value to set the assigned risk level for the hydraulic works.

However, a univariate approach in complex problems ignores the effect of significant variables interrelation leading to different risk levels for each quantity of interest and resulting in a completely wrong estimate of the risk. For example, if one considers the flood inflow in a lake around which cities and villages are positioned, the variable to be investigated in relation to the risk assessment is the lake water level. It is obvious that the same water level may occur from very different flood hydrographs, even when the same initial water level and the same rate curve of outflows are considered. This is a consequence of the interaction of at least three joint variables: hydrograph's peak flow, volume and shape.

Consequently, a multivariate framework is needed for a more realistic view of the matter at hand. In recent years, the application of copula functions has facilitated overcoming the inadequacies of multivariate distributions as the problem is handled from two non-interwinding aspects: the dependence structure of the pair of variables and the marginal distributions.

The main objective of this study is to investigate whether it is possible to find, in a multivariate space, a region where all the multivariate events produce 'risk' lower or greater than a fixed mean inter-occurrence of failures of one time every T-years. Preliminary results seem to confirm that it is impossible to obtain uniqueness in the definition.